Thermal Design and Validation of Mars 2020 Gas Dust Removal Tool (gDRT)

ICES Paper 2019-249

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International Conference on Environmental Systems,
Boston, MA 2019

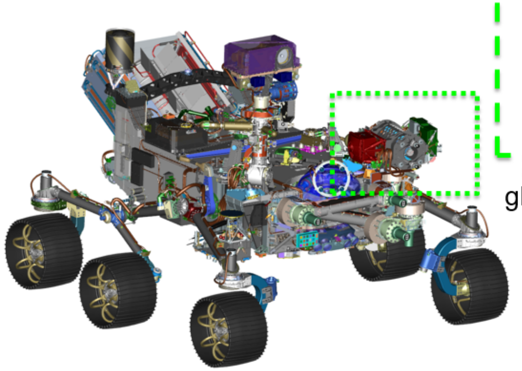
Outline

- gDRT Introduction
- Development Testing
- Hardware Configuration
- Thermal Design
- Thermal Testing
- Analysis for Mars Operation
- Conclusions

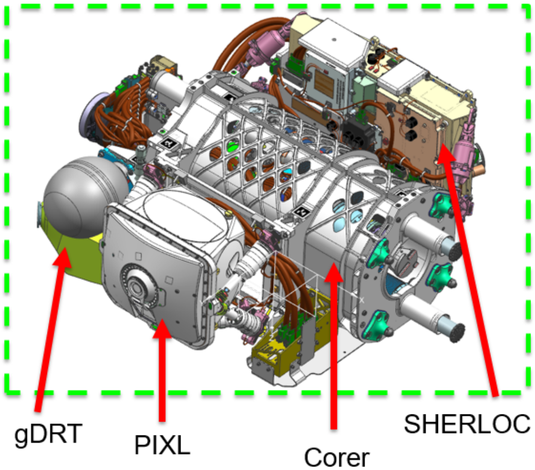
gDRT Introduction

- Tool to remove dust from abraded surfaces for imaging by Mars 2020 science instruments, PIXL and SHERLOC
- Part of Turret Assembly at the end of the Rover's Robotic Arm
- Baselined for flight in June 2016

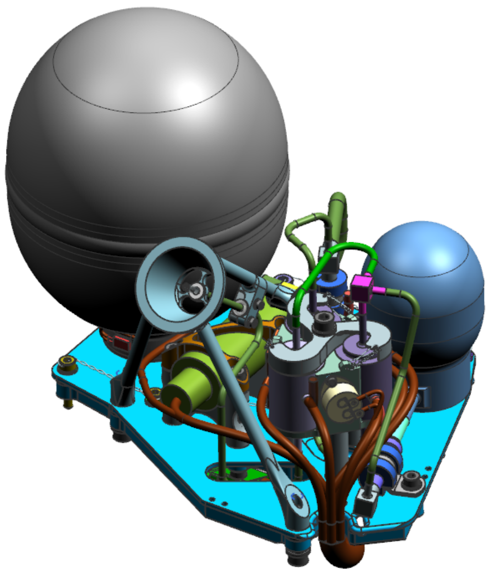
Mars 2020 Rover



Turret Assembly

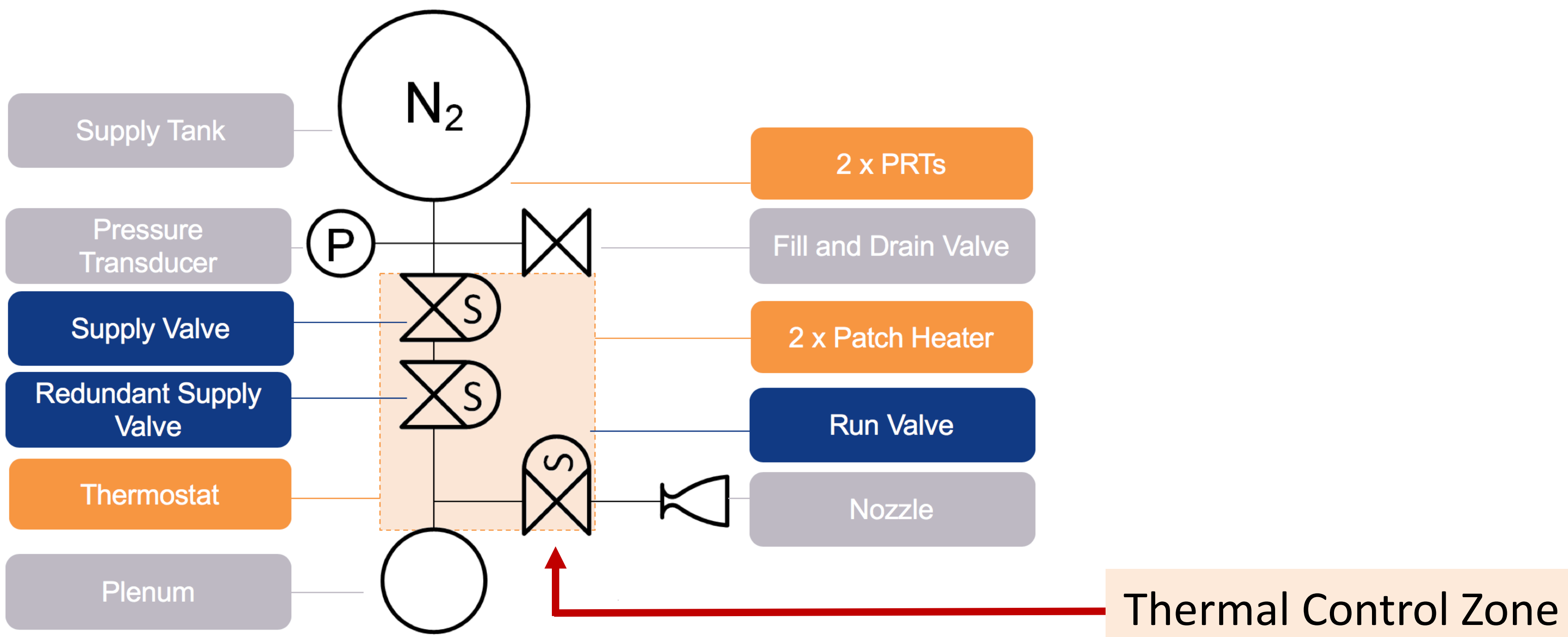


gDRT



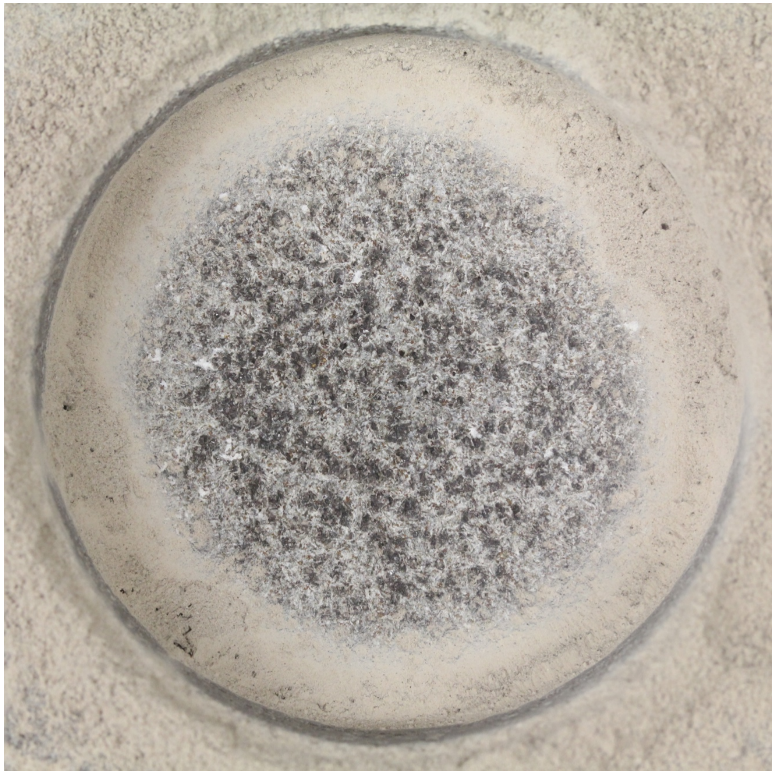
gDRT Overview

- Requirements: clear dust off a circular patch 40mm in diameter from an abraded surface with 16mm depth
- System components:



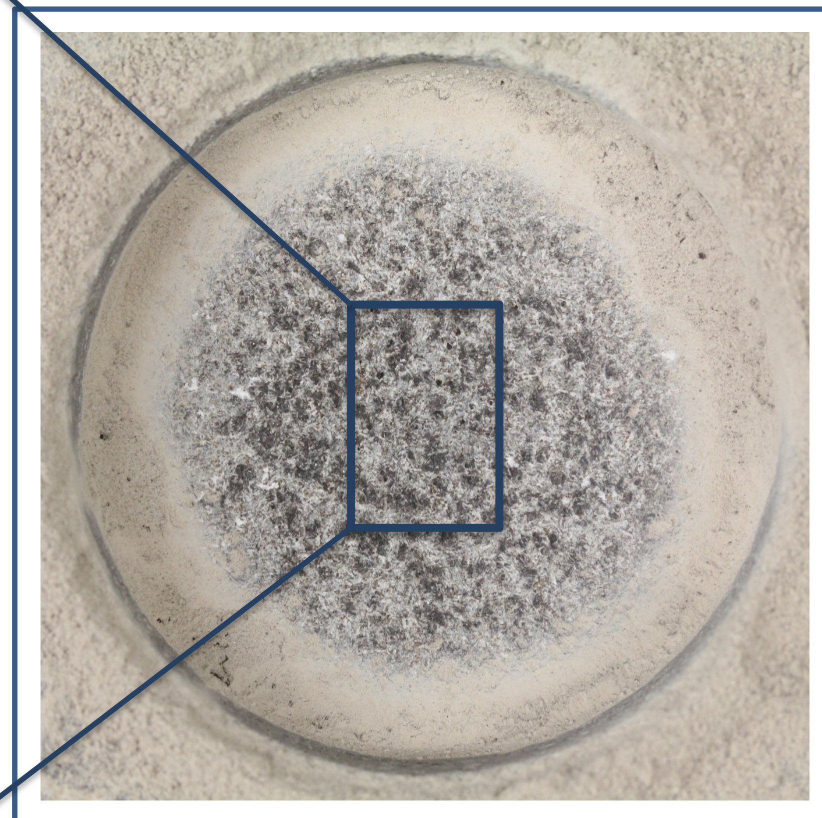
Development Testing

Development Testing Results

Before	After
	

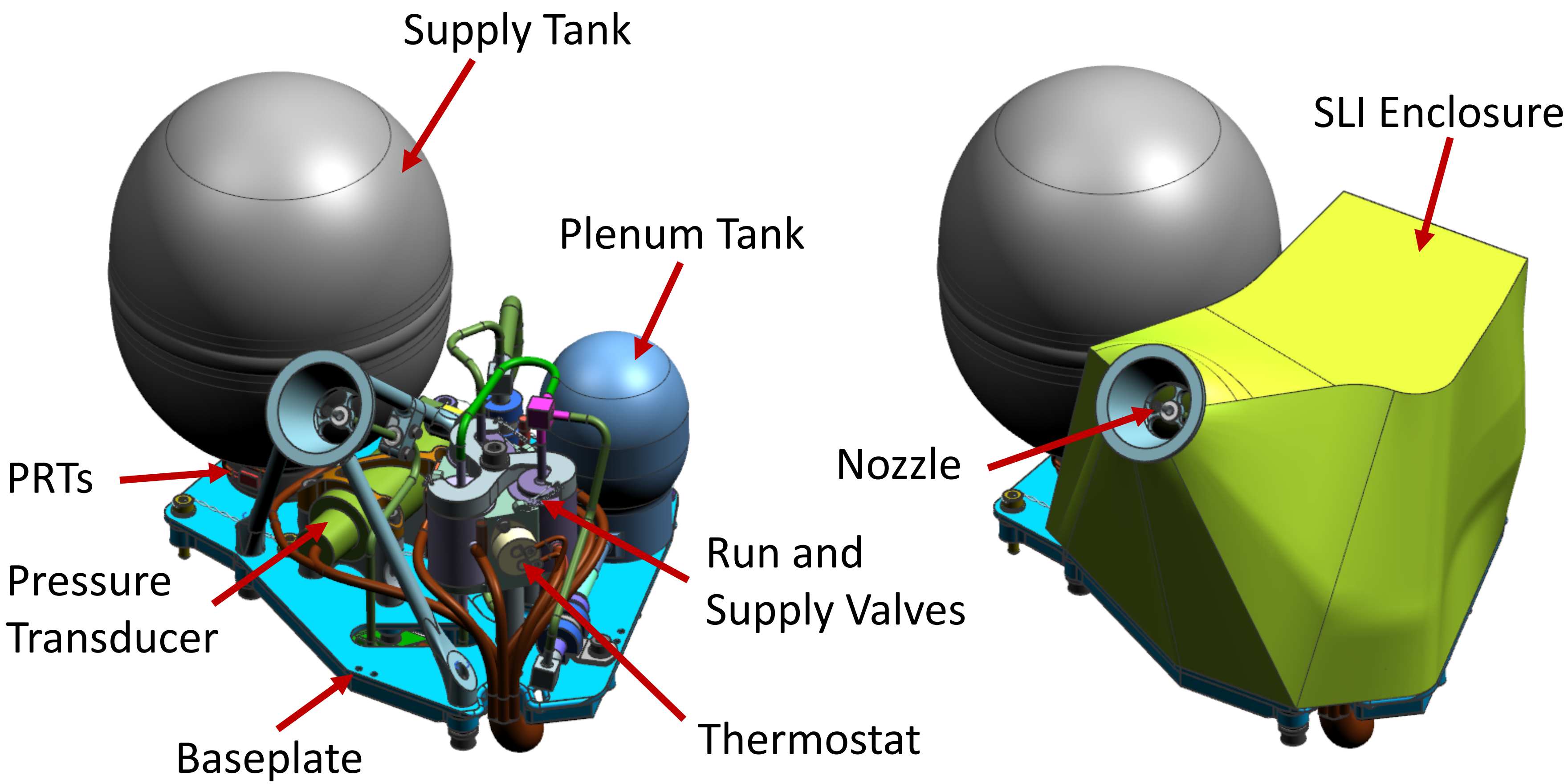
Development Testing Results

After



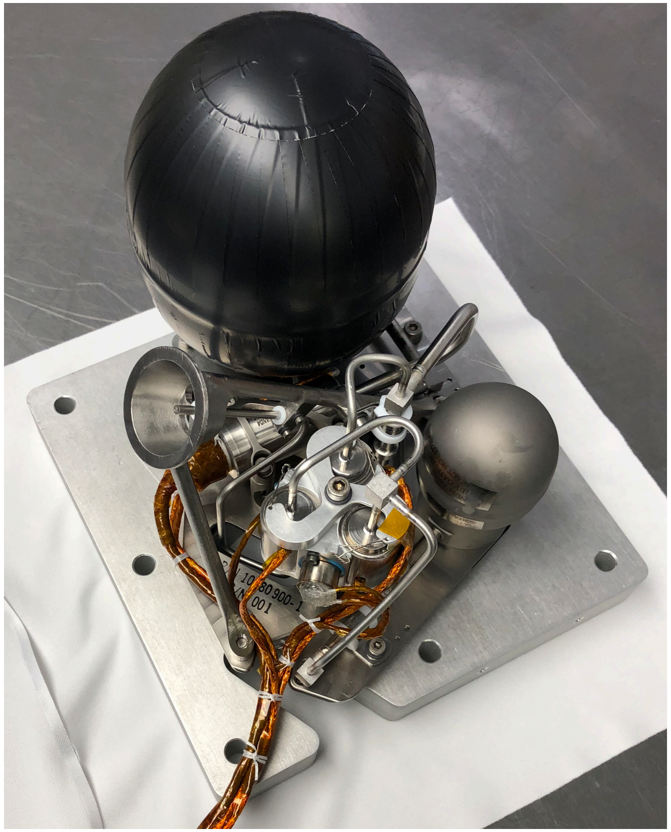
Hardware CAD

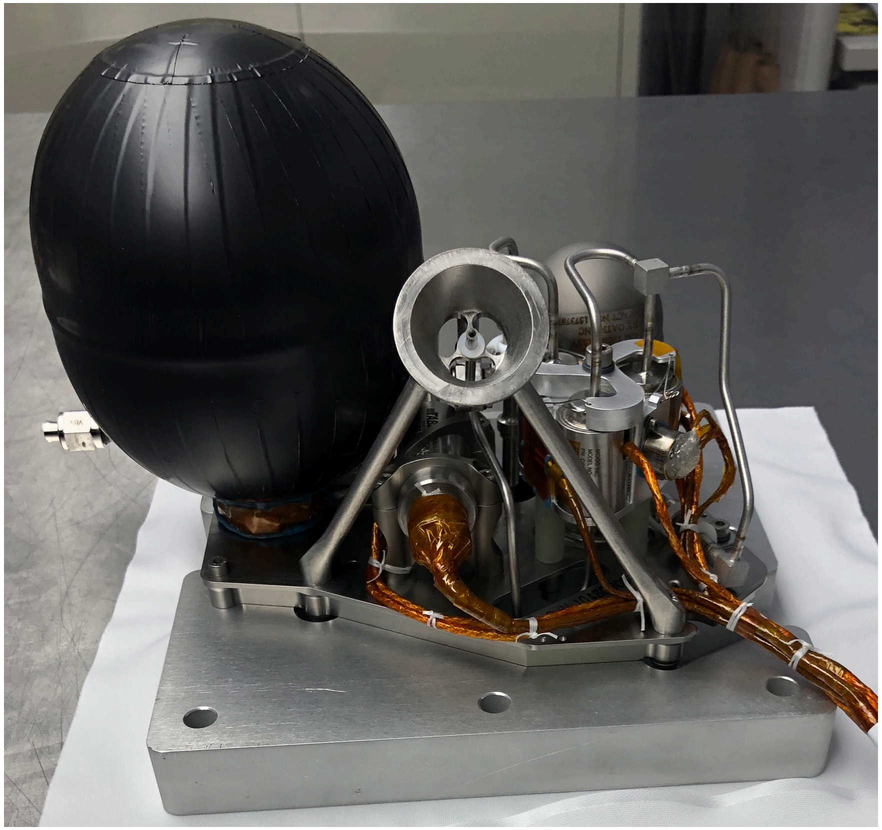
- Final design configuration:



Flight Hardware

- Flight gDRT assembly ready for integration onto Turret
  - SLI Enclosure installed post-Turret integration

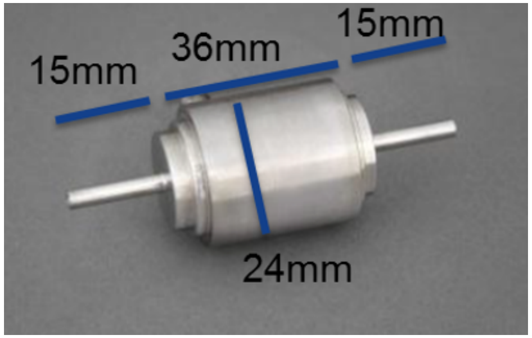




Temperature Requirements

- All hardware has Allowable Flight Temperature range of -128C to +50C *

- * Run and Supply Valves are commercially sourced components qualified by the manufacturer to -20C
  - Risk of gas leakage below this temperature

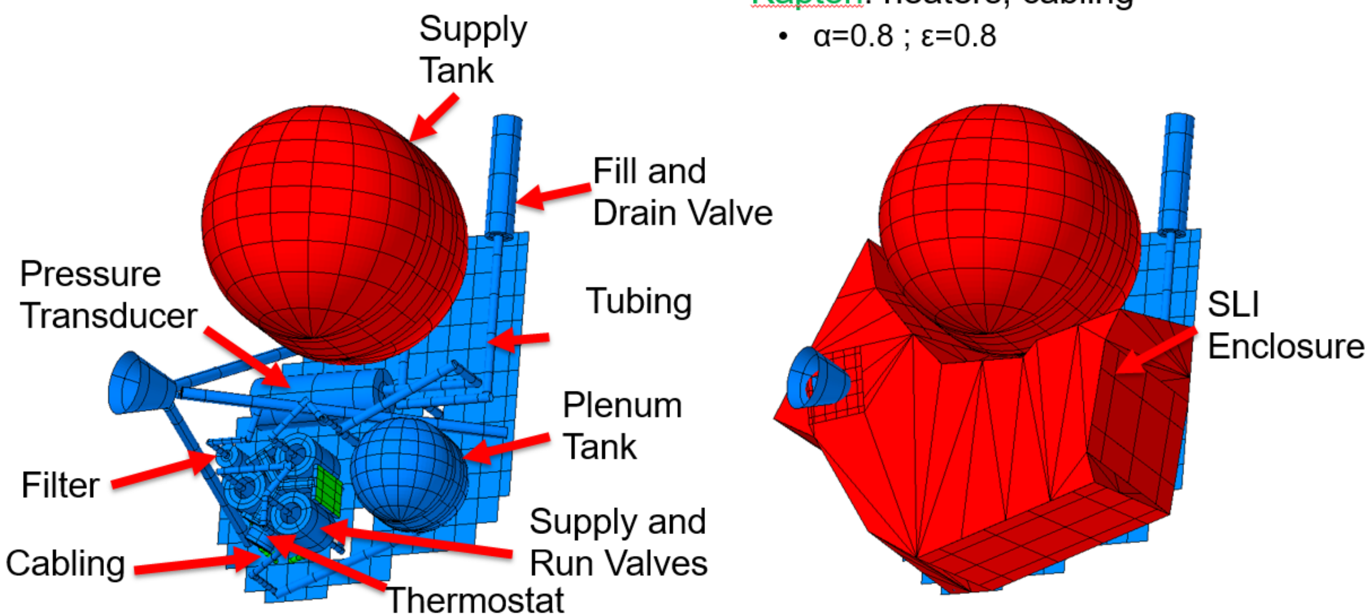


- Parallel path implemented Mars 2020:

1. Qualify valves to -135C
   - Ongoing activity with positive results
2. Implement thermal control to keep the valves warm in case qualification is unsuccessful

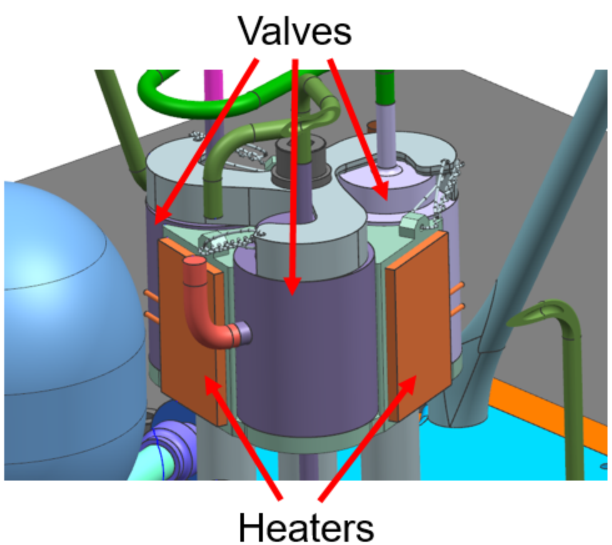
Thermo-optical Properties

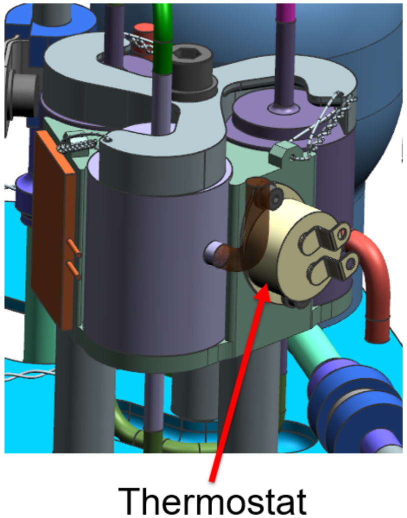
- Exterior surfaces are primarily Black Kapton
- Thermal Desktop model:
  - Optical Properties
    - Black Kapton: supply tank, enclosure exterior, baseplate
      - α=0.92 ; ε=0.88
    - Bare metal: tubing, enclosure interior, baseplate
      - α=0.5 ; ε=0.1
    - Kapton: heaters, cabling
      - α=0.8 ; ε=0.8



Valve Thermal Control

- Thermostatically controlled heaters
- Valves kept thermally isolated from other gDRT hardware (details in next slide) to minimize heater energy
- Thermostat setpoint of -64C to -75C selected based on early risk reduction testing

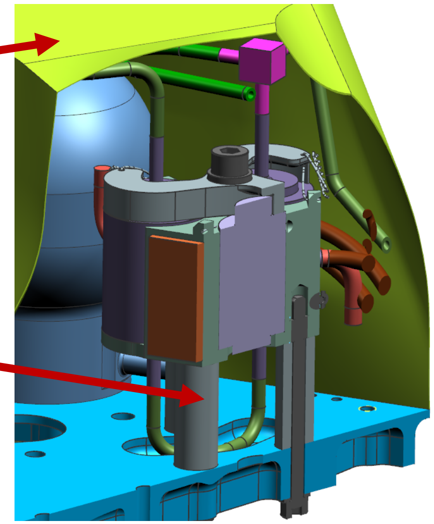


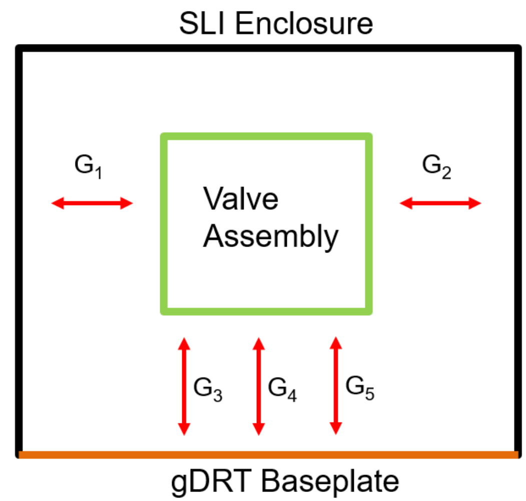


Heater Properties	
Width (mm)	18.5
Length (mm)	28
Resistance (Ω)	300
Power at 22V (W)	1.6
Power at 28V (W)	2.6
Power at 32.8V (W)	3.6
Watt Density at 32.8V (W/in^2)	5

Valve Isolation

1. SLI Enclosure:
   - provides CO_2 gas gap
   - blocks view to cold sky
2. G10 isolators and titanium bolts to isolate from baseplate

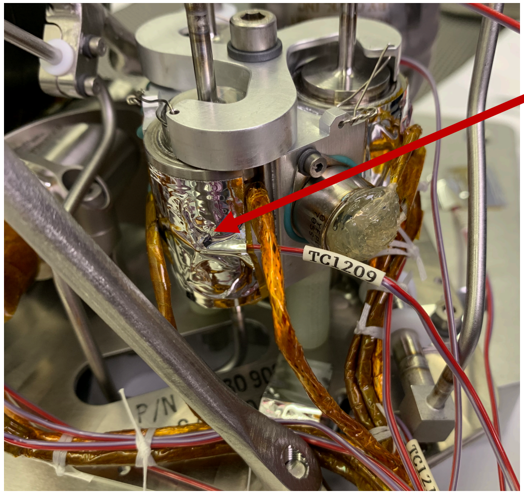




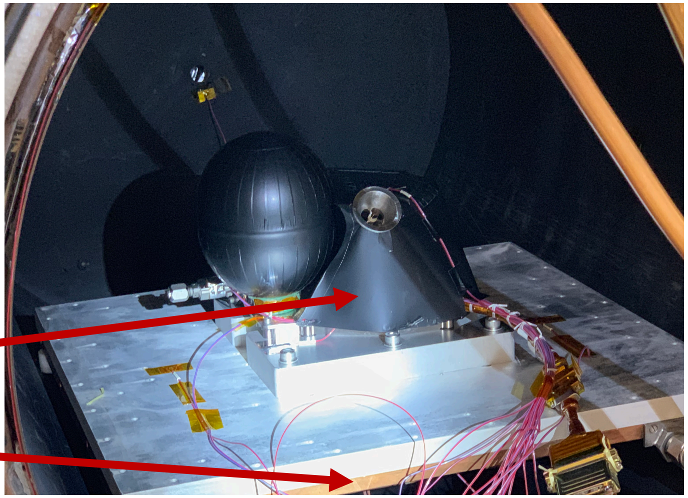
Conductor	Value (W/C)	Description
G_1	0.0023	Radiation heat loss from valves (ε=0.1) to SLI enclosure interior and baseplate (ε=0.1)
G_2	0.0064	CO_2 gas-gap, with a 1” nominal gap on all sides
G_3	0.0143	Valve assembly through 3, 1” long titanium bolts and G-10 isolators
G_4	0.0350	Conduction through cabling for thermostat, heaters, and valves
G_5	0.0220	Conduction through steel tubes leaving the valve assembly
Net	**0.08**	

Thermal Testing

- Thermal test environment:
  - GN_2 atmosphere at 8 torr
  - Chamber shrouds and heat exchanger held at -135C
- Functional testing:
  - Valves operated at +70C and -135C
  - Heaters turned on with boundary conditions at -135C



Thermocouples on Valves

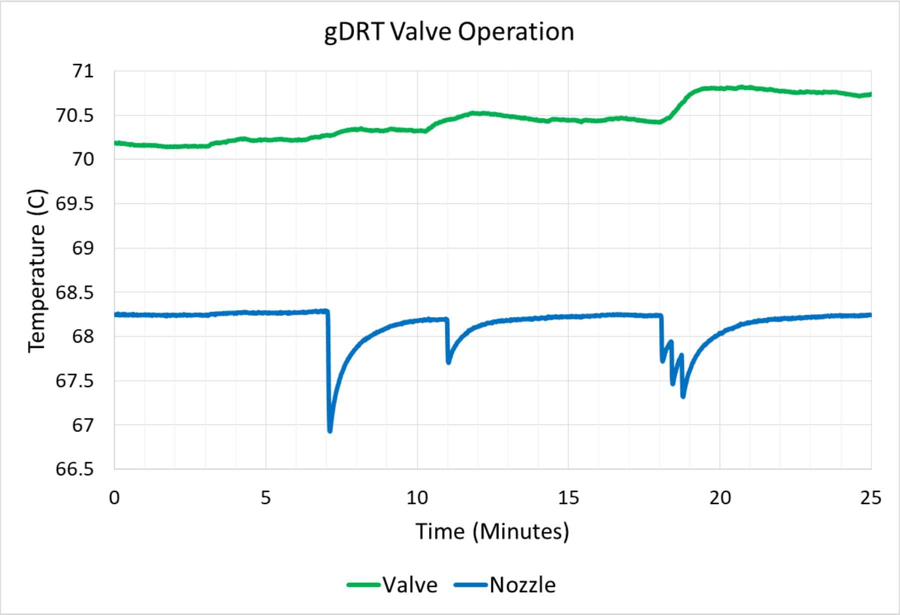


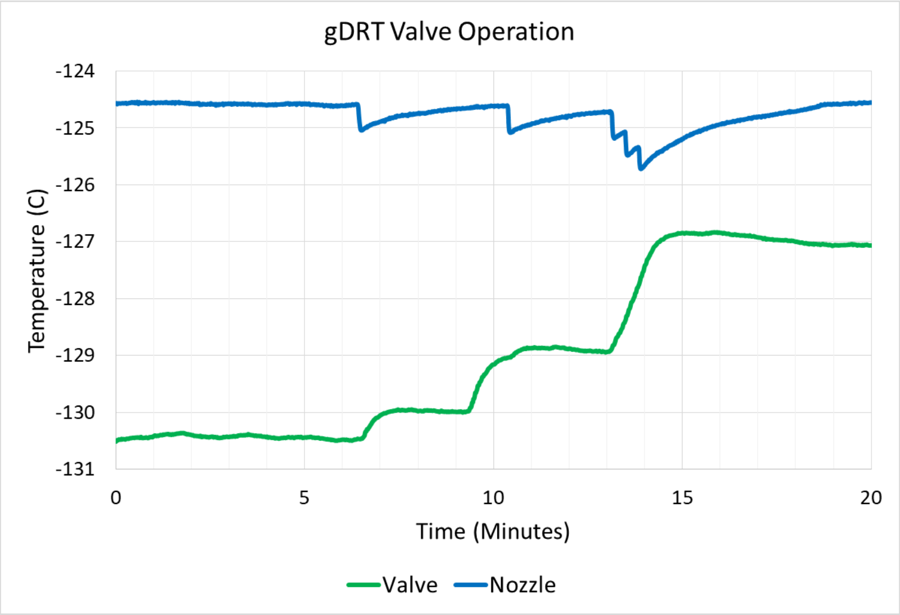
SLI Enclosure

Heat Exchanger

Thermal Testing Results

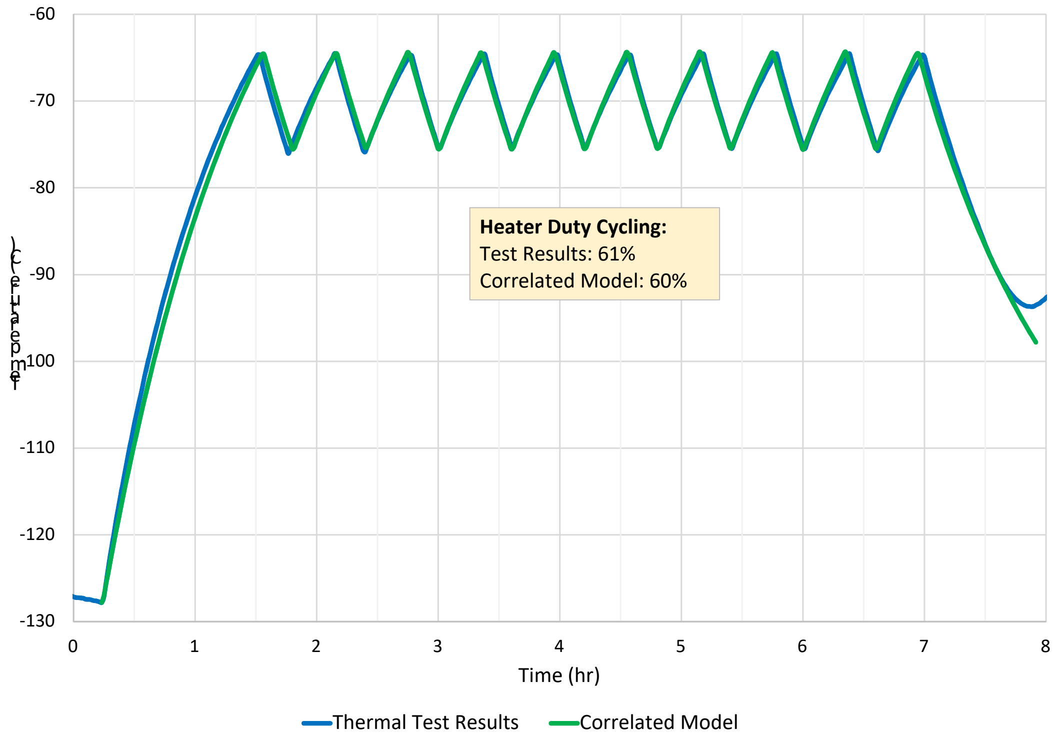
- Valves successfully operated at +70C and -131C
  - Valves rise in temperature due to self heating
  - Nozzle drops in temperature due to gas expansion / JT cooling





Thermal Testing Results

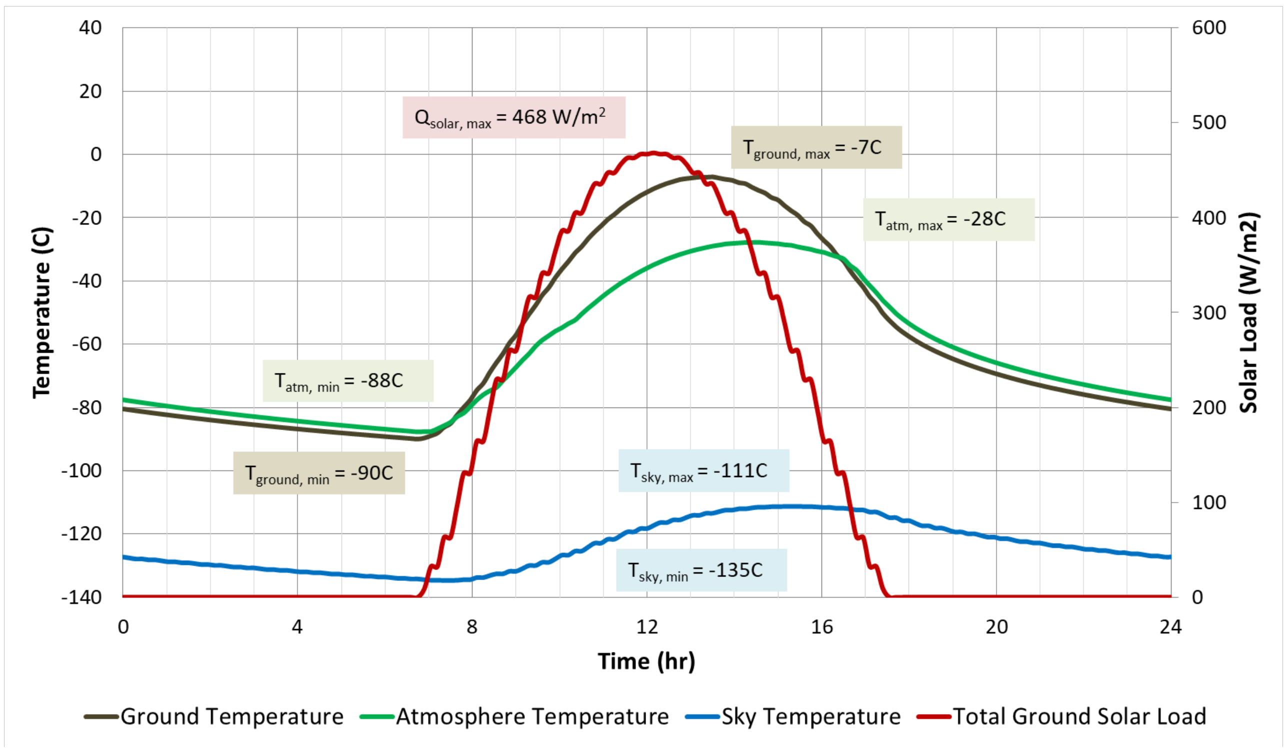
- Heaters successfully maintained valve temperatures within the desired set points
- Test data allowed for thermal model correlation:



Mars Environment

- Jezero landing site selected for Mars 2020
- Worst Case Cold Environment:

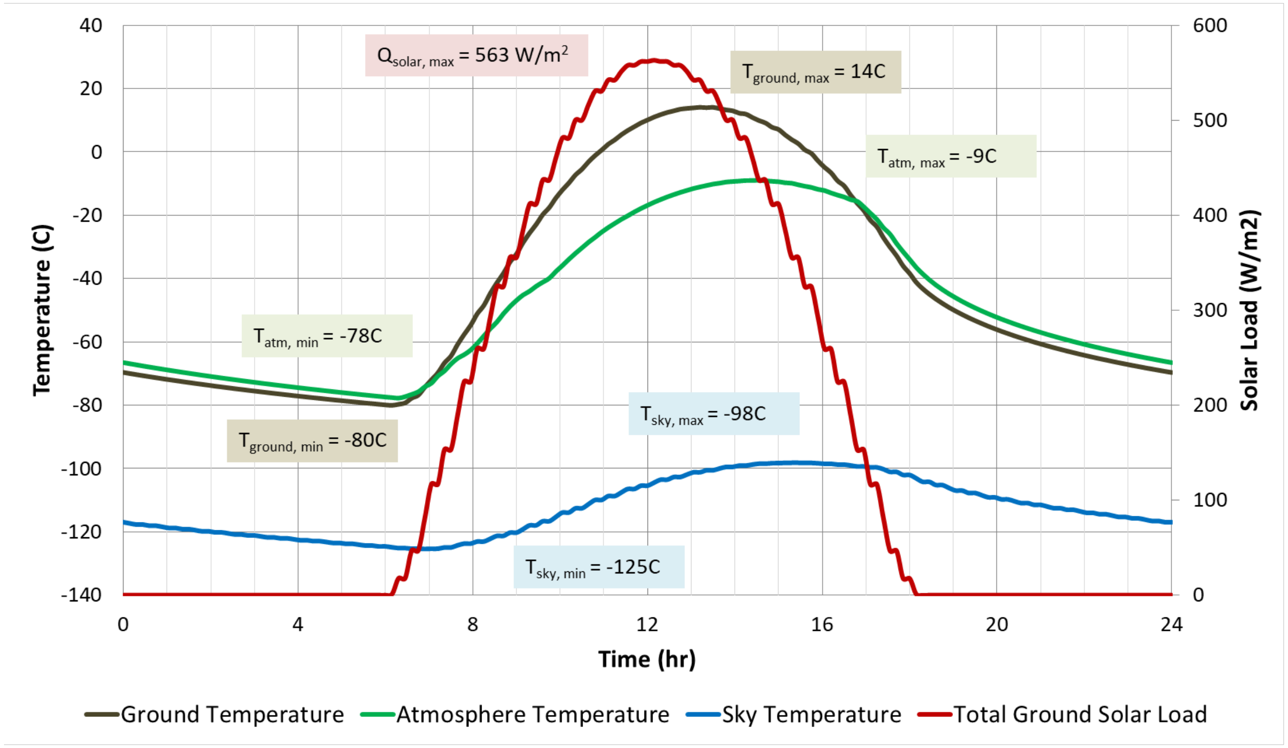
18.4N , L_s = 281° , albedo = 0.1773 , τ = 0.2



Mars Environment

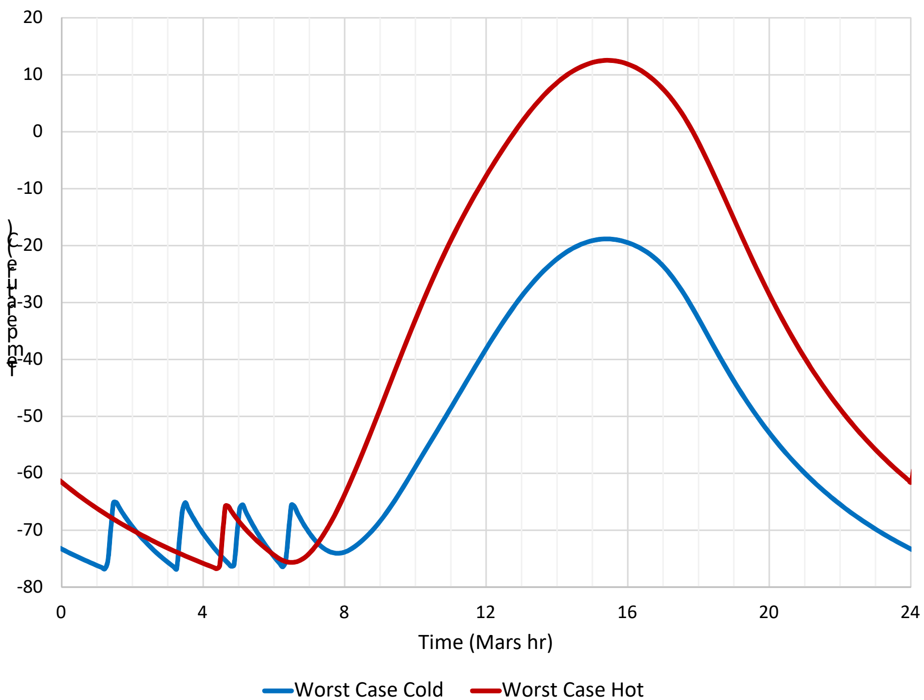
- Jezero landing site selected for Mars 2020
- Worst Case Hot Environment:

18.4N , L_s = 179° , albedo = 0.1467 , τ = 0.2



Analysis for Mars

- Correlated thermal model used to predict heater performance at Jezero landing site
- Max energy: 2.6W-hr ; Rover daily energy budget ~ 2400W-hr
- Max duty cycle: 15% ; meets JPL design guideline of < 80%



	WCC	WCH
Energy Consumption (W-hr)	2.6	0.4
Peak Duty Cycle (%)	15	N/A

Conclusions

- Thermal control of the gDRT run and supply valves has been designed, implemented, and validated
  - Able to maintain valves between -64C and -75C thermostat setpoint during Mars operation with minimal impact to Rover energy budget

- Qualification of the valves to -135C is ongoing, with promising results thus far
  - If qualification is successful, heating will only be used if a gas leak is detected

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Acknowledgements

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Government sponsorship acknowledged.